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George S. Springer and Antony Jameson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Aeronautics and Astronautics
Stanford University
Stanford, CA 94305

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The following document describes the use of the funds provided by the Air Force Office of Scientific Research to create a high performance laboratory for parallel fluid dynamics calculations. In the months following the submission of the proposal a sizable cost-sharing commitment was made by the Department of Aeronautics and Astronautics and the School of Engineering at Stanford Univer-sity which allowed for a substantial increase in the scope of the equipment to be purchased. A large part of the equipment is already in place, and the final pieces will be arriving during the following weeks. The equipment acquired with the combination of the funds presented above includes the following: 1. Origin2009 Compute Server 2. Silicon Graphics Octane Graphics Workstations. The intent of this proposal was to facilitate the development of parallel computing methods for computational fluid dynamics calculations. Initially we had foreseen the acquisition of high per-formance workstations to pre- and post-process the data obtained from simulations performed on DoD supercomputers. With the new equipment it is now possible to, in addition, perform the initial development and debugging of the programs in-house. This mode of operation enables us to use DoD facilities in a truly productive fashion, and it avoids the long time delays during the early development stages due to network connections and the usual batch environment of today's supercomputers.

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Department of Aeronautics and Astronautics
Stanford University
Stanford, California 94305
U.S.A

High Performance Workstations for the Pre- and Post-Processing of Parallel Fluid Dynamics Calculations

March, 1 1997 – February 28, 1998

George S. Springer
Principal Investigator
Department of Aeronautics and Astronautics
Stanford University

Antony Jameson
Professor
Department of Aeronautics & Astronautics
Stanford University

Contents

1 Summary

The following document describes the use of the funds provided by the Air Force Office of Scientific Research to create a high performance laboratory for parallel fluid dynamics calculations. In the months following the submission of the proposal, a sizable cost-sharing commitment was made by the Department of Aeronautics and Astronautics and the School of Engineering at Stanford University which allowed for a substantial increase in the scope of the equipment to be purchased. A large part of the equipment is already in place, and the final pieces will be arriving during the following weeks. All equipment purchases obtained the approval of AFOSR (Maj. Scott Schreck,202-767-7902).

2 Available Funding

The initial version of the proposal called for a total of $218,229, $185,495 of which would be provided by AFOSR and $32,735 would be cost shared by Stanford University. These funds were to be used for the acquisition of 5 Silicon Graphics Solid Impact 10000 workstations (1 Gbyte of memory), high speed network interface cards, and a color printer.

With the discovery of a special Stanford University - Silicon Graphics agreement that provides a 60% discount over standard list prices and the further commitment of the Department of Aeronautics and Astronautics and the School of Engineering to accommodate the arrival of professors Jameson and Alonso, a total of $255,928 were made available as cost sharing to this proposal. Additional sources of funding were gathered to make the final equipment purchase possible.

The generous contribution of AFOSR provided the seed for the creation of a state-of-the-art Computational Fluid Dynamics (CFD) laboratory at Stanford University.

3 Acquired Equipment

The equipment acquired with the combination of the funds presented above includes the following:

1. **Origin2000 Compute Server.** This computer is a Distributed Shared Memory machine with a total of 16 processors, 4 Gbytes of memory, and 36 Gbytes of storage space produced by Silicon Graphics Inc. It can be used for the solution of moderately sized computational fluid dynamics problems using two kinds of parallel implementation: automatic parallelization with the current generation of SGI compilers, or message passing using standards such as MPI (Message Passing Interface) and PVM (Parallel Virtual Machine). List Price: $1,103,557. Purchase Price: $441,423.

2. **Silicon Graphics Octane Graphics Workstations**. These two computers will each have 2 R10000 processors and a total of 1 Gbyte of memory. Their SSI graphics engine allows the real time visualization of complex analysis and design CFD calculations. List Price: $108,420. Purchase Price: $70,473

4 Use of Acquired Equipment

The intent of this proposal was to facilitate the development of parallel computing methods for computational fluid dynamics calculations. Initially we had foreseen the acquisition of high performance workstations to pre- and post-process the data obtained from simulations performed on

DoD supercomputers. With the new equipment it is now possible to, in addition, perform the initial development and debugging of the programs in-house. This mode of operation enables us to use DoD facilities in a truly productive fashion, and it avoids the long time delays during the early development stages due to network connections and the usual batch environment of today's supercomputers.

In particular, the acquired equipment will be used for the research projects outlined in our proposal. Only a brief description is given here. Several projects are already taking advantage of the installed equipment:

- *Development of Efficient Flow Solvers.* Further algorithmic improvements are necessary to make the turnaround of Reynolds-Averaged Navier-Stokes calculations fit comfortably within the design cycle.

- *Parallel Implementations.* Though most of the porting work was performed at Princeton during the past 2 years, additional efforts are needed to refine the techniques and to treat changing environments with the use of dynamic load balancing algorithms.

- *Unsteady and Aeroelastic Flows.* Parallel implementations of the unsteady flow solvers are starting to be used to investigate the unsteady behavior of fluid phenomena on complete aircraft configurations, as well as the interaction of changing pressure fields with flexible structures (flutter in particular).

- *Automatic Design Methods for Complex Configurations Using the Navier-Stokes Equations.* Initially, a multiblock meshing strategy is being used for the aerodynamic shape optimization of complete aircraft configurations using adjoint methods. This work requires fundamental research that will benefit from the compute server recently acquired.

Two other projects are currently being started and will make use of the equipment for the duration of its service life.

- *Aerodynamic and Multidisciplinary Optimization.* With aerodynamic shape optimization methods in a maturing stage, additional high fidelity modelling of other disciplines is necessary to achieve higher performance in the design. Initially, the addition of structural models will be attempted.

- *Aerodynamic Shape Optimization for Unsteady Flows.* The combination of efficient unsteady flow solvers with aerodynamic optimization methods can be used to create optimum designs for flows such as those present in helicopter rotors in forward flight and turbomachinery components.